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PATENT
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TEMPERATURE VARIANCE REDUCTION USING VARIABLE PENETRATION DILUTION JETS

GOVERNMENT RIGHTS

[0001] The invention was made with Government support under contract number N00019-02-C-3002, awarded by the U.S. Navy. The Government has certain rights in this invention.

BACKGROUND OF THE INVENTION

[0002] The present invention generally relates to gas turbine engine systems and, more particularly, to combustor assemblies for gas turbine engines.

[0003] Combustor assemblies are integral components of gas turbine engines. The combustor assembly may be positioned in flow communication with a compressor, a fuel injector and one or more turbines. During engine operation, pressurized air from the compressor and fuel from the fuel injector may enter the combustor. The resulting fuel/air mixture may be ignited to produce a high temperature combustion gas stream. The hot combustion gas then flows downstream to the turbines for energy extraction.

[0004] The extreme temperature environment resulting from the hot combustion gas stream limits the useful operating time and ultimately component life of the combustor and turbines. The turbine and combustor components are very sensitive to variations and extremes in temperature. Methods for mitigating the negative effects of the high temperature combustion gas have been disclosed.

[0005] A multihole patch for a combustor liner has been disclosed in U.S. Pat. Application No. 2003/0200752. In the described method, patches of dissimilar sized holes are used for cooling the liner wall. Cooling of the walls is provided by a combination of orifices behind nuggets and groups of small holes drilled at an angle in regions requiring augmented cooling. Although the described method may reduce the thermal stress to the combustor liner, a reduction in the thermal stress experienced by the downstream components is still needed. Further, a reduction in gas stream temperature variation is also needed.

[0006] Another combustor liner has been disclosed in U.S. Pat. No. 6,260,359. The described liner is provided with two rows of close-coupled dilution holes at different axial positions. The first row of holes (primary) is of uniform size and has an equiangular spacing. The second set of dilution holes is of varying size to minimize hot-streaks formed by the fuel injectors and to provide a uniform circumferential pattern factor (temperature variation). Although the described combustor liner may reduce temperature variation across the plane of the combustor outlet, the disclosed combustor is an annular combustor and does not address the need for reductions in scroll wall temperatures, as annular combustor configurations do not include scrolls.

[0007] A combustor for a turbine engine is described in U.S. Pat. No. 6,606,861. The disclosed combustor is provided with major and minor dilution jets to regulate the spatial temperature profile of the exhaust gases from the combustor. Although the disclosed combustor may reduce temperature variation, the described combustor is also an annular combustor and, therefore, does not address the need for scroll wall temperature reductions. An annular combustor or can-annular (separate cans in a common annulus) arrangement may not be suitable for some turbine engine applications.

[0008] A single can and scroll type configuration may be desirable for some applications. The single can and scroll configuration has a single fuel injector. The need for only one fuel injector may simplify engine design, maintenance, and repair, thus reducing the associated cost. The single can and scroll

configuration allows for the use of a fuel injector that is larger than the fuel injectors suitable for use in annular combustors. This is advantageous in ameliorating fuel injector coking. Fuel injector coking is a function of the dimensions of the fuel injector's internal passages. Larger fuel injectors have larger internal passages and therefore are more resistant to coking. Yet another advantage of the single can and scroll configuration is that the thermal stress on downstream components is reduced due to the better pattern factor through the scroll.

[0009] Although there are several advantages of the single can and scroll arrangement, one disadvantage is that the scroll has a relatively large surface area. Depending on the engine operating cycle, the scroll may require air cooling and sufficient air may not be available to allow effusion or film cooling over such a large surface. Additionally, for some applications, the conventional dilution cooling arrays have met with limited success. Conventional dilution cooling arrays comprise equi-sized dilution orifices and may provide inadequate penetration of cooler air to the core of the hot combustion gases in some applications. Although penetration of the dilution air may be increased by increasing the combustor pressure drop, this is not a desirable option since the pressure drop represents a parasitic loss on the engine performance.

[0010] As can be seen, there is a need for improved combustor assemblies. Additionally, improved can/scroll combustors are needed wherein the scroll cooling requirements are reduced. Further, dilution cooling arrays having improved core penetration without an increase in combustor pressure drop are needed. Combustor improvements allowing for easy retrofit to existing designs also are needed. Improved combustors are needed wherein temperature variation across the combustor exit plane is reduced.

SUMMARY OF THE INVENTION

[0011] In one aspect of the present invention, a combustor assembly

comprises a combustor can, the combustor can suitable for use with a scroll; and a variable penetration dilution jet array, utilizing orifice arrays of non-equal diameter, positioned in an aft portion of the combustor can there through, the variable penetration dilution jet array capable of simultaneously reducing combustor exit temperature variance and providing a film cooling flow to the scroll.

[0012] In another aspect of the present invention, a can and scroll combustor assembly comprises a combustor can; a scroll positioned downstream and in flow communication with the combustor can; a plurality of scroll cooling openings through the combustor can, the scroll cooling openings capable of providing dilution air and a film cooling flow to the scroll; and a plurality of core penetrating openings through the combustor can, the core penetrating openings capable of providing dilution air to a hot gas flow core of the combustor can.

[0013] In still another aspect of the present invention, a variable penetration dilution jet array for an assembly having a can and a scroll comprises a plurality of core penetrating openings positioned circumferentially about the can; a plurality of scroll cooling openings positioned circumferentially about the can, the scroll cooling openings are offset from the core penetrating openings; and a plurality of intermediate openings positioned circumferentially about the can, the intermediate openings are offset from the core penetrating openings.

[0014] In yet another aspect of the present invention, a combustor assembly for a turbine engine having a scroll comprises a combustor can; a plurality of core penetrating openings circumferentially positioned about an axial plane of the combustor can, the core penetrating openings uniformly spaced; and a plurality of scroll cooling openings circumferentially positioned about the axial plane of the combustor, the scroll cooling openings uniformly spaced.

[0015] In a further aspect of the present invention, an apparatus for a can and scroll combustor assembly comprises at least one core penetrating opening through an aft end portion of the can, the core penetrating opening capable of providing dilution air to a hot gas flow core of the can; at least one scroll cooling

opening through the aft end portion of the can, the scroll cooling opening capable of providing a film cooling flow to the scroll; and at least one intermediate opening through the aft end portion of the can, the intermediate opening capable of reducing temperature variation at the exit plane of the can.

[0016] In still another aspect of the present invention, a method of providing dilution air to a can and scroll assembly comprises the steps of projecting a first portion of dilution air through at least one axial plane of the can such that a film cooling flow is provided to the scroll; and projecting a second portion of dilution air through at least one axial plane of the can such that the temperature of a hot gas flow core of the can is reduced.

[0017] These and other features, aspects and advantages of the present invention will become better understood with reference to the following drawings, description and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] Figure 1 is a cross-sectional schematic view of a combustor assembly according to one embodiment of the present invention;

[0019] Figure 2a is a plan view of a combustor assembly according to one embodiment of the present invention;

[0020] Figure 2b is a plan view of a combustor assembly according to another embodiment of the present invention; and

[0021] Figure 3 is a perspective view of a combustor can and scroll assembly according to one embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0022] The following detailed description is of the best currently contemplated modes of carrying out the invention. The description is not to be taken in a limiting sense, but is made merely for the purpose of illustrating the general

principles of the invention, since the scope of the invention is best defined by the appended claims.

[0023] Broadly, the present invention generally provides gas turbine combustor assemblies and methods for producing the same. The combustor assemblies produced according to the present invention may find beneficial use in many industries including aerospace and industrial applications. The combustor assemblies of the present invention may be beneficial in applications including aircraft propulsion, naval propulsion, electricity generation, pumping sets for gas and oil transmission, automobile engines, and stationary power plants. This invention may be useful in any gas turbine engine application.

[0024] The current invention provides for a variable penetration of dilution air into the hot core by employing differential dilution orifice sizing around the circumference of the combustor can. Unlike the prior art, the present invention provides dilution air at several radial locations simultaneously, as shown in Figure 1. Alternating smaller (scroll cooling openings 43) and larger holes (core penetrating openings 44) may provide for improved mixing uniformity with the smaller jets (scroll cooling openings 43) giving shallow penetration and the larger jets (core penetrating openings 44) enabling deep core penetration. With the present invention, a more uniform plane of cool dilution air 50 may be introduced near the exit of the combustor can 41 to limit the variance in the temperature distribution experienced by the turbine components. In effect, the dilution air 50 may be projected at several radial locations simultaneously. In this way, a large dilution jet penetration may be achieved without resorting to the high combustor pressure loss of prior art methods. The largest jets (core penetrating openings 44), having the largest penetration may reach the hot gas flow core 52 and reduce the maximum temperature of the gases leaving the combustor can 41. The smallest jets (scroll cooling openings 43) may not penetrate the hot gas flow excessively and air from these jets may remain in the near wall region 53 simultaneously providing near-wall dilution of the combustor gas stream and forming a layer of cooler gases that may protect the

downstream scroll walls.

[0025] In one embodiment, shown in Figure 2a, the present invention provides a combustor can assembly 40 for a gas turbine engine (not shown). The combustor can assembly 40 may comprise a combustor can 41 having a variable penetration dilution jet array 42 there through. The variable penetration dilution jet array 42 may be positioned in the aft portion 46 of the combustor can 41. Unlike the prior art, the variable penetration dilution jet array 42 may comprise a plurality of scroll cooling openings 43, a plurality of core penetrating openings 44 and a plurality of intermediate openings 45.

[0026] During engine operation, dilution air 50 from the scroll cooling openings 43 may provide a film cooling flow to a downstream scroll 54 (shown in Figure 3), which also is unlike the prior art. The scroll cooling openings 43 may reduce or eliminate the need for dedicated scroll wall cooling, be it effusion or film cooling. The film cooling flow provided by the present invention may reduce scroll cooling requirements to the point where the use of a single can and scroll arrangement may be feasible even in relatively hot engine cycles. Dilution air 50 from the core penetrating openings 44 may provide cooling air to the hot gas flow core 52, which also is unlike the prior art. The intermediate openings 45, in combination with the core penetrating openings 44 and the scroll cooling openings 43, may provide an improved pattern factor at the exit plane 55 of the combustor can 41.

[0027] A useful combustor can 41 of the present invention may comprise any combustor can 41 suitable for use with a downstream scroll 54. The diameter of the combustor can 41 may be uniform along the length of the combustor can 41, such as a cylindrical combustor can (not shown). The diameter of the combustor can 41 may vary along the length of the combustor can 41, such as a tapered aft end combustor can 47 shown in Figure 2a.

[0028] The variable penetration dilution jet array 42 may be positioned within the aft portion 46 of the combustor can 41. The aft portion 46 may be the downstream end of the combustor can 41 and may have an axial length of less

than about one third the axial length of the combustor can 41. The variable penetration dilution jet array 42 may be positioned in one or more axial planes 48. For example, the variable penetration dilution jet array 42 may comprise a plurality of core penetrating openings 44 positioned in a first axial plane 49a and a plurality of scroll cooling openings 43 positioned in a second axial plane 49b, as shown in Figure 2b. Alternatively, the variable penetration dilution jet array 42 may comprise a plurality of core penetrating openings 44, a plurality of intermediate openings 45 and a plurality of scroll cooling openings 43 all of which are positioned in the same axial plane 48, as in Figure 2a. Another embodiment of the present invention may include core penetrating openings 44 and intermediate openings 45 in a first axial plane 49a, intermediate openings 45 and scroll cooling openings 43 in a second axial plane 49b, and scroll cooling openings 43 in a third axial plane (not shown). The variable penetration dilution jet array 42 of the present invention may be positioned within one or more axial planes 48; each axial plane 48 may comprise one or more dilution jet opening forms. As used herein, a dilution jet opening form is an opening selected from the group consisting of scroll cooling opening 43, core penetrating opening 44 and intermediate opening 45. A useful variable penetration dilution jet array 42 may comprise at least two dilution jet opening forms. The useful number of axial planes 48 and useful positions of dilution jet opening forms may vary with engine design and combustor dimensions. Computational fluid dynamics (CFD) analysis may be useful in determining the desired number of axial planes 48 and the desired positions of dilution jet opening forms for a particular engine design.

[0029] The scroll cooling openings 43 of the variable penetration dilution jet array 42 may be capable of providing film cooling to a downstream scroll 54. Dilution air 50 may pass through the scroll cooling openings 43 and remain in the near wall region 53 as it flows axially downstream to provide a film cooling flow to a combustor scroll 54, thereby reducing scroll cooling requirements. The near wall region 53 may be the area within the combustor can 41 that is

radially outward from the hot gas flow core 52. The scroll cooling openings 43 may be positioned such that they are equally circumferentially spaced in at least one axial plane 48 of the combustor can 41. For a variable penetration dilution jet array 42 having scroll cooling openings 43 in more than one axial plane 48, the scroll cooling openings 43 in one axial plane 48 may be offset from the scroll cooling openings 43 in another axial plane 48. The number of scroll cooling openings 43, the diameter of the scroll cooling openings 43, and the location of the scroll cooling openings 43 may vary with engine design and combustor dimensions. CFD analysis may be useful in determining the desired number, diameter and location of the scroll cooling openings 43. The diameter of useful scroll cooling openings 43 may depend on factors including combustor can 41 diameter. The number of useful scroll cooling openings 43 may depend on factors including combustor can 41 circumference. For example, for a combustor can 41 having a diameter of 5¼ inches and a circumference of 16½ inches, the useful number of scroll cooling openings 43 may be 8 and the diameter of a useful scroll cooling opening 43 may be about 0.200 inches. Although the diameter of a scroll cooling opening 43 may vary with engine design, the diameter of a useful scroll cooling opening 43 may be between about 0.100 inches and about 0.300 inches.

[0030] The core penetrating openings 44 of the variable penetration dilution jet array 42 may be capable of providing dilution air 50 to the hot gas flow core 52. Dilution air 50 passing through the core penetrating openings 44 may reduce the temperature of the hot gas flow core 52. The core penetrating openings 44 may be positioned such that they are equally circumferentially spaced in at least one axial plane 48 of the combustor can 41. For a variable penetration dilution jet array 42 having core penetrating opening 44 in more than one axial plane 48, the core penetrating openings 44 in one axial plane 48 may be offset from the core penetrating openings 44 in another axial plane 48. The number of core penetrating openings 44, the diameter of the core penetrating openings 44, and the location of the core penetrating openings 44

may vary with engine design and combustor dimensions. CFD analysis may be useful in determining the desired number, diameter and location of the core penetrating openings 44. The diameter of useful core penetrating openings 44 may depend on factors including combustor can 41 diameter. The number of useful core penetrating openings 44 may depend on factors including combustor can 41 circumference. For example, for a combustor can 41 having a diameter of 5¼ inches and a circumference of 16½ inches, the useful number of core penetrating openings 44 may be 4 and the diameter of a useful core penetrating opening 44 may be about ½ inch. Although the diameter of a core penetrating opening 44 may vary with engine design, the diameter of a useful core penetrating opening 44 may be between about 0.400 inches and about 0.800 inches.

[0031] The intermediate openings 45 of the variable penetration dilution jet array 42 may be capable of improving circumferential and radial mixing uniformity and thereby further reducing the variance in the temperature distribution experienced by the downstream turbine components. The intermediate openings 45 may be positioned such that they are equally circumferentially spaced in at least one axial plane 48 of the combustor can 41. For a variable penetration dilution jet array 42 having intermediate openings 45 in more than one axial plane 48, the intermediate openings 45 in one axial plane 48 may be offset from the intermediate openings 45 in another axial plane 48. The number of intermediate openings 45, the diameter of the intermediate openings 45, and the location of the intermediate openings 45 may vary with engine design and combustor dimensions. CFD analysis may be useful in determining the desired number, diameter and location of the intermediate openings 45. The diameter of useful intermediate openings 45 may depend on factors including combustor can 41 diameter. The number of useful intermediate openings 45 may depend on factors including combustor can 41 circumference. For example, for a combustor can 41 having a diameter of 5¼ inches and a circumference of 16½ inches, the useful number of intermediate

openings 45 may be 4 and the diameter of a useful intermediate opening 45 may be about 0.300 inches. Although the diameter of an intermediate opening 45 may vary with engine design, the diameter of a useful intermediate opening 45 may be between about 0.200 inches and about 0.500 inches. The diameters of the intermediate openings 45 of a variable penetration dilution jet array 42 may vary so that the dilution air 50 may be projected at more than three radial locations simultaneously.

[0032] Methods for producing the combustor can assemblies 40 and the variable penetration dilution jet arrays 42 are known in the art. Useful methods for forming the variable penetration dilution jet array 42 may include electrical discharge machining (EDM) or laser drilling. Laser drilling may be useful for producing the variable penetration dilution jet array 42. The variable penetration dilution jet array 42 may comprise a plurality of dilution jet opening forms. The dilution jet opening forms may vary in diameter. When compared with one another, the scroll cooling openings 43 may have the smallest diameters and the core penetrating openings 44 may have the largest diameters. The intermediate openings 45 may have diameters that are larger than the scroll cooling openings 43 and smaller than the core penetrating openings 44.

[0033] The combustor can assemblies 40 of the present invention may be easily retrofitted into existing turbine engines. The sizing of the scroll cooling openings 43, core penetrating openings 44 and intermediate openings 45 may be set to a certain percentage above and below nominal to maintain pressure drop and airflow consistent with uniform orifice sizing.

Example

[0034] A combustor can and scroll assembly for an engine was produced. The combustor can had an axial length of 7 inches and a diameter of 5¼ inches. The variable penetration dilution jet array comprised four core

penetrating openings each having a diameter of 0.470 inches, eight scroll cooling openings, each having a diameter of 0.200 inches, and four intermediate openings, each having a diameter of 0.280 inches. The variable penetration dilution jet array was positioned in one axial plane 1½ inches forward from the aft end edge of the combustor can. The dilution jet opening forms were evenly distributed around the circumference of the combustor can as shown in Figure 2a. During engine operation, scroll temperatures remained acceptable even though effusion cooling to the scroll had been reduced.

[0035] As can be appreciated by those skilled in the art, the present invention provides improved combustor assemblies and methods for their production. A combustor assembly capable of reducing scroll cooling requirements is provided. Further, dilution arrays capable of improved combustor core penetration and improved pattern factor are provided. Also provided are improved combustors that can be easily retrofitted into existing turbine engines. Further, a can and scroll combustor assembly having an improved pattern factor is provided.

[0036] It should be understood, of course, that the foregoing relates to exemplary embodiments of the invention and that modifications may be made without departing from the spirit and scope of the invention as set forth in the following claims.